Congresso annuale
Dipartimento di Scienze Fisiche e Tecnologie della Materia

DAL PNRR ALL'IMPATTO: INFRASTRUTTURE, COMPETENZE E VISIONE

Trasformare investimenti straordinari
in capacità durature

Consiglio Nazionale delle Ricerche
Piazzale Aldo Moro 7, Roma

4-5 giugno 2026

ABSTRACT DELLE SESSIONI PARALLELE

CNR | Dipartimento Scienze Fisiche e Tecnologie della Materia

AULA CONVEGNI	**16:30**

Age-It: Ageing Well in an Ageing Society

The PNRR public-private alliance to generate socioeconomic, biomedical and technological solutions for an Active and Healthy Italian ageing society

PIETRO SICILIANO

Institute for Microelectronics and Microsystems IMM-CNR, Lecce

General information

Age-It is a PNRR "Extended Partnership" Research Program that aims at generating **a quantum leap in Italy's contribution to research and innovation on ageing, making it a leader in research as well as in strategic European and global value chains**. Applying a **holistic, interdisciplinary**, and **problem-solving approach**, Age-It, with its 26 partners, overcomes the fragmentation of different perspectives on ageing, involving a critical mass of partners including research and educational institutions, care providers and civil society associations, businesses and industries.

The programme activity has been scheduled in 10 Spokes, 4 of them (spokes 2, 6, 8 and 9) include CNR participation. In particular, **Spoke 8** ***"Interventions and technologies to reduce the burden of age-related diseases, disorders and disabilities"*** and **Spoke 9** ***"Advanced Gerontechnologies for active and healthy ageing"*** are related to the development of new technological solutions (devices, sensors, etc.) with the direct involvement of DSFTM, having also the leadership of Spoke 9.

Examples of activities in charge to DSFTM in these two spokes include the development of innovative technological solutions for monitoring and supporting the daily life of older adults, particularly: 1) design and adopt of innovative technologies in different life domains and environments, like home, hospital, community; 2) integration of non-intrusive sensors, AI and smart technology for socio-health monitoring and support, 3) Sensors and MEMS technologies for environmental safety and monitoring, where air quality in buildings is a critical determinant of healthy living 4) development of AI and robotic sensing technologies to provide support for prevention, early disease detection and health monitoring (e.g., wearable sensors for physiological signal monitoring, to be used also in home environment).

AGE.It's Follow up and Next Starting Actions

1) ***<u>SAGE-It: Smart Technological solutions for Active and Healthy Ageing</u>***

The Hub has participated to the call MUR ***D.D. No. 307 of 18-03-2025*** with the following proposal ***"SAGE-It: Smart Technological solutions for Active and Healthy Ageing"***, that has been funded and will start on June 1st 2026. It includes the following three projects, all of them including DSFTM and one of them coordinated by DSFTM itself, aimed at Italy's least developed regions (Basilicata, Calabria, Campania, Molise, Puglia, Sardinia):

a) **SAGE-RISE -** a national research and innovation initiative aimed at validating and enhancing high-tech solutions for active and healthy ageing., SAGE-RISE aims to increase the technological maturity of solutions (from TRL 3–5 to 6–8)
b) **SAGE-CONNECT** - Distributed Territorial Ecosystems for Innovation in Active and Healthy Ageing (***under the coordination of DSFTM***) – a strategic initiative that aims to consolidate and enhance a national Innovation Ecosystem in the fields of active ageing and healthy longevity
c) **SAGE-SKILLS -** created to systematically address the challenge of active ageing in the world of work, proposing an innovative model of continuous, inclusive training aimed at enhancing the skills of senior workers (over 50).

2) **<u>Italian Institute of Ageing _I³</u>**

The **Italian Institute of Ageing** will be launched in July 2026 with the aim to be the Italian integrated scientific pole, acting as an international scientific and technological standard reference.

Presence of DSFTM in the Research Programme

<u>DSFTM participation</u>: 3 Institutes (IMM, Nanotec, IFN)

<u>Critical mass</u>: 6 PI, 5 TD and other coworkers not reported in the cost statement of critical mass

CNR Participation in the VITALITY Ecosystem: From Advanced Materials Research to Regional Innovation and Sustainability

GIANLUCA GUBBIOTTI

CNR-Istituto Officina dei Materiali (IOM), 06123 Perugia, Italy

The Consiglio Nazionale delle Ricerche (CNR) partecipated to the VITALITY Ecosystem project, as associated partner ofthe University of Perugia, contributing to the advancement of innovation, digitalization, and sustainability in Central Italy under the framework of the Italian National Recovery and Resilience Plan (PNRR). As an affiliated partner of the University of Perugia, CNR had actively involved in Spokes 9 and 10, dedicated respectively to nanomaterials and biomaterials. The CNR contribution integrates multidisciplinary expertise from several research institutes and highly qualified researchers, supporting the development of advanced materials and innovative technologies for industrial, environmental, and biomedical applications. Through state-of-the-art analytical platforms and characterization techniques—including electron microscopy, atomic and magnetic force microscopy, hyperspectral imaging, Raman and infrared spectroscopy, and high-performance computational infrastructures—CNR provides both experimental and theoretical support for the design and optimization of nanostructured and bio-based materials. In addition, CNR fosters technology transfer, collaboration with enterprises, and specialized training activities for industrial stakeholders, contributing to the creation of new technological hubs, spin-offs, and sustainable innovation pathways within the regional ecosystem. Overall, the CNR participation strengthens the scientific and technological capacity of the VITALITY project, promoting cross-disciplinary research and accelerating the transition toward a more resilient and sustainable innovation ecosystem in Abruzzo, Marche, and Umbria regions involved in the project. A major contribution of the CNR within the VITALITY ecosystem was also the scientific and technological support provided to the establishment of the Nanomat Technological Hub ("Polo Nanomat") inaugurated in Gualdo Tadino. The hub represents a strategic infrastructure for the transfer of advanced nanomaterials technologies toward industrial applications and regional innovation. Through the involvement of CNR institutes and researchers, the Polo Nanomat has become a reference center for advanced materials characterization, spectroscopy, nanostructure fabrication and collaboration with local enterprises. Two dedicated to products and instrumentation catalogs have been released to support professionals and companies in choosing the most suitable solutions for their needs. The initiative strengthens the connection between academic research, public research institutions and industrial stakeholders, fostering the development of innovative technologies, start-ups and sustainable manufacturing processes within the Umbria regional ecosystem.

AULA CONVEGNI	17:00

From FAIR to AI4Nature: Pervasive, Trustworthy, and Sustainable AI for Ecological Transition and Biodiversity

COSIMO DISTANTE

Institute of Applied Sciences and Intelligent Systems „Eduardo Caianiello“

The FAIR (Future Artificial Intelligence Research) Extended Partnership – Spoke 8 – has developed methods, prototypes, and pilots for fair, robust, and transparent pervasive AI. Key outcomes include fairness-aware frameworks (HAMLET4Fairness), quantum neural networks, legal benchmarks (LEXTREME, AMELIA), healthcare pipelines (dermatological diagnosis, autism prediction, bone age assessment), education dashboards (dropout prevention, TRL6), human-AI creativity tools (JammAI, ImproVerse), and manufacturing/space edge intelligence. All datasets, code, and pipelines are open-sourced on GitHub, Zenodo, and SoBigData.

Building on these results, the **AI4Nature Innovation Hub** represents the operational evolution of FAIR, translating foundational AI models and architectures into concrete services for biodiversity and the ecological transition. By integrating FAIR outcomes with the expertise of the National Biodiversity Future Centre (NBFC), AI4Nature delivers a distributed national infrastructure based on physical and virtual nodes in less developed Italian regions (Campania, Puglia, Calabria, Sicily, Sardinia). Through an advanced service catalog (NatureGPT, multimodal Data Hub, environmental robotics), the Hub provides businesses, public administrations, and local communities with ready-to-use tools for ecosystem monitoring, restoration, and sustainable governance, ensuring scalability, interoperability, and long-term sustainability.

AULA CONVEGNI	17:15

The CNR contribution to the Tuscany Health Ecosystem (THE): integrated research and disruptive innovation in healthcare

LEONIDA GIZZI

Istituto Nazionale di Ottica (CNR-INO), Pisa, Italy

The Tuscany Health Ecosystem (THE) is a major national initiative for health innovation funded by the Italian National Recovery and Resilience Plan, bringing together all Tuscan universities, research institutions and companies in a multidisciplinary programme. Within THE, CNR participates through its Pisa and Florence Institutes in five thematic Spokes and leads Spoke 1 on "Advanced Radiotherapies and Diagnostics in Oncology" with scientific and management coordination entrusted to CNR-INO. The CNR contribution mobilizes nine institutes across three departments, combining biomedical sciences, physical sciences and technologies of matter, engineering, ICT and enabling technologies. This integrated structure supports a cross-cutting research agenda with a CNR budget of approximately 13 M€, including 2.6 M€ allocated through cascade calls that funded eleven projects and seventeen beneficiaries, with a strong commitment to southern Italy.

The scientific programme spans advanced oncological diagnostics and radiotherapies, technologies for health and wellbeing, nanotechnologies for diagnosis and therapy, regulatory and technology-transfer studies, and biotechnology and imaging in neuroscience. In Spoke 1, CNR-INO works with IFC, IN, NANO and ITB, together with UNIFI, UNIPI and INFN, on FLASH radiotherapy, ultra-fast ionizing-radiation beams for VHEE/FLASH approaches based on next-generation laser and plasma technologies, and innovative radiopharmaceuticals from synthesis to clinical translation. Complementary activities include wearable- and artificial-intelligence-based studies for active ageing, computational platforms for personalized oncology, optical nanostructures and smart scaffolds for advanced therapies, biomarker-detection platforms, medical-device regulation, patenting and transfer of new radiopharmaceuticals. Neuroscience activities reinforce infrastructures and expertise in imaging, cellular models and artificial intelligence, including brain-in-a-dish models and AIassisted screening. In the technology transfer effort, a new start-up was launched by CNR-INO and is now filed to become a spinoff of CNR.

Overall, the CNR role in THE demonstrates how a distributed research organization can act as a strategic engine for translational health disruptive innovation. By integrating competences across five Spokes, managing resources effectively and promoting international visibility through scientific events and high-impact publications, the CNR contribution strengthens the path toward healthcare that is more effective, intelligent and person-centred.

AULA CONVEGNI	17:30

QOLOSSUS: the Italian quantum photonic computer

ROBERTO OSELLAME

Istituto di Fotonica e Nanotecnologie, Consiglio Nazionale delle Ricerche (CNR-IFN), Milan, Italy

Quantum photonics is one of the contender platforms that aim at developing a full-fledged quantum computer. Toward this final goal, we have realized an intermediate scale machine named QOLOSSUS by leveraging the investments of the PNRR project ICSC (high-performance computing), the innovative solutions that we have developed in the framework of the PNRR project NQSTI, and the support of multiple EU projects.

QOLOSSUS, hosted and assembled at the Sapienza Università di Roma, is based on a quantum photonic processor developed and fabricated by the CNR-IFN in Milan exploiting femtosecond laser writing (Fig. 1) [1]. The unique features of this technology enabled the fabrication of a fully programmable and high-fidelity photonic processor where the quantum states of single photons can be precisely manipulated implementing innovative quantum algorithms [2]. In particular, in this platform we demonstrate scalability both on-chip, by achieving a record-high number of optical modes for an integrated platform, and at the system level, via modular interconnections between different chips.

QOLOSSUS does not yet include error correction, but can execute relevant algorithms that demonstrate the potential of this approach for quantum randomness engineering [3] and quantum machine learning [4,5].

This presentation will discuss the current status of the quantum machine and its future developments.

[1] G. Corrielli et al., Nanophotonics 10 (2021), 3789-3812.
[2] V. Cimini et al., Advanced Photonics 5 (2023), 016005.
[3] F. Hoch et al., Nature Photonics 19 (2025), 12-19.
[4] F. Hoch et al., Nature Communications 16 (2025), 902.
[5] L. Monbroussou et al., Advanced Photonics 7 (2025), 066012.

PNRR – NEFERTARI Research and Development of optical plasma diagnostics for fusion

GIORGIO DILECCE[A], PAOLO FRANCESCO AMBRICO[A], DOMENICO ACETO[A], ARSHAD HUSSAIN[A,B], DOMENICO BRUNO[2], OLGA DE PASCALE[2]

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In this WP we have developed two facilities, one experimental, the other one theoretical, based on the expertise of the Bari group in the diagnostics and modelling of non-equilibrium plasmas. The experimental facility is a projection of our consolidated expertise in the optical diagnostics of gas discharges into applications to fusion-relevant studies and the development of new diagnostic strategies. In particular, we have acquired instrumentations for three main diagnostic applications:

1. Installation for studies on Laser Induced Breakdown Spectroscopy (LIBS) by fs laser, for the in-situ elemental analysis of surface modifications and, in particular, fuel retention in plasma facing materials. The relevant instrumentation is a fs laser facility, a state-of-the arts spectrograph and a set of optical microscope/optical profilometer to characterize the craters made by the laser for a quantitative depth profilometry;

2. Installation for optical emission spectroscopy (OES), to support CR models of hydrogen emission. The relevant instrumentation is a fast gated optical spectrograph;

3. Installation for laser spectroscopy studies, with a double aim. One is the study of the kinetics of electronic states of hydrogen, to support the CR models, for which a tuneable ps OPO laser has been acquired. The other aim is the analytical application of Laser Induced Fluorescence (LIF) to the detection of transient species and, in particular H atoms, for which a ns tuneable laser has been acquired capable of wavelengths down to 204 nm.

Studies and developments of diagnostic techniques require small scale plasma test facilities that can run continuously and every day, on which the diagnostics can be tested, improved and adapted to the final user's demands. To this end we have developed and built two discharge systems based on a DC reflex IBC discharge scheme which is capable of high-density plasma production even at low, order of 1 Pa, gas pressure. One of these discharges, with two cathodes, is used for loading with deuterium test samples for LIBS and for discharge-assisted LIBS. The other, with 8 cathodes, will be used for spectroscopy studies.

Some details on LIBS and OES studies will be given.

IBS superconducting wires development for high field magnets: a collaboration between CNR-SPIN and CERN supported by the PNRR-Infrastructure IRIS

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[a] *CNR-SPIN, Genova, Italy*
[b] *UniGe, DIFI, Genova, Italy*
[c] *CERN, Geneve, Switzerland*

CNR-SPIN and CERN collaborate in a project forming part of the HFM – High Field Magnets Programme. The project consists in carrying out preliminary research works related to the development of Iron Based Superconducting wire (IBS) produced with the Powder In Tube (PIT) technology. This project is the first phase of a potential future technology development aiming at developing a new generation of high-temperature superconductors (HTS) for accelerator magnets. The scope of this collaboration is to develop the technological steps toward a new generation of HTS superconducting wires originated from the 122-type IBS materials. The very high upper critical field (Hc_2) in addition to the low anisotropy makes IBS quite attractive for use in high-field magnets. Furthermore, high-field magnets can operate not only at liquid helium temperature but also at higher temperature of around 20 K. Some critical aspects shall be studied: the manipulation and reaction of the elements to produce high quality powders with clean grain boundaries; the feasibility of the powder densification and the powder grains texturing within a wire produced through a scalable mechanical process. Such project furthermore can count on the support of the PNRR-Infrastructures initiative named IRIS, a new Innovative Research Infrastructure on applied Superconductivity. The hub of this distributed infrastructure is the INFN-LASA (Laboratorio Acceleratori e Superconduttività Applicata) and extends to various poles, to regroup and coordinate the largest part of the Italian community active on superconductivity and magnetism, included the CNR-SPIN institute. The scope of IRIS is to provide a unique new infrastructure fostering basic study of superconductivity and magnetism design and practical experimentation with fast turnaround cycle of new superconducting conductors, magnets and devices, and finally for testing in operative conditions large scale magnets and device manufactured in industry.

New technologies and methodologies for traceability, quality, safety, measurements and certifications: the activity of DSFTM in the Spoke 9 of CN-Agritech

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a CNR-INO

b CNR-IFN

c CNR-ISASI

d CNR-NANOTEC

Safeguarding agrifood chains is a modern imperative. This contribution outlines the DSFTM's work within the Centro Nazionale Agritech (Spoke 9), an initiative focused on enhancing the efficiency of farm processes through advanced sensing and data analysis. Central to this effort was the robust collaboration inside CN-Agritech between CNR, ENEA, Universities and companies to develop devices for measuring food quality, safety, authenticity, traceability and sustainability of production systems.

Together, we deployed spectroscopic sensors (Raman and infrared) for monitoring plant stress and fruit quality in fresh produce chains, while MIP electrochemical sensors allowed pesticides detection. Ochratoxin A was detected via high-Q photonic dielectric aptasensors and food quality was analyzed by portable multispectral imaging in the cereal chain. Clostridia and E. coli were detected by Raman spectroscopy to assess milk safety.

This study was supported by the“Agritech National Research Center” funded by the European Union Next-Generation EU (Piano Nazionale di Ripresa e Resilienza.

iNEST - Interconnected Nord-Est Innovation Ecosystem

L. POLETTO

CNR - Istituto di Fotonica e Nanotecnologie, via Trasea 7, Padova

iNEST è l'Ecosistema dell'Innovazione finanziato dal PNRR, con baricentro nel territorio del Nord-Est italiano. Il consorzio riunisce tutti gli atenei del Triveneto – Università di Bolzano, Trento, Udine, IUAV di Venezia, Padova, Ca' Foscari Venezia, Verona e Trieste – insieme alla SISSA, al CNR e all'OGS (Istituto Nazionale di Oceanografia e di Geofisica Sperimentale).

L'impianto progettuale di iNEST si fonda su un uso esteso delle ICT e punta allo sviluppo di soluzioni innovative orientate al benessere delle persone, alla diffusione della cultura e alla crescita economica e imprenditoriale dei territori.

L'iniziativa ha messo in relazione università, centri di ricerca, imprese e istituzioni pubbliche con l'obiettivo di rafforzare la competitività del Nord-Est e di promuovere nuove traiettorie di sviluppo fondate sulla conoscenza. La struttura dell'Ecosistema è organizzata in nove Spoke tematici: Ecosistemi montani; Salute, alimentazione e stili di vita; Manifattura avanzata e sostenibile; Città, architettura e design sostenibile; Ambienti di vita e di lavoro smart e sostenibili; Turismo, cultura e industria creativa; Smart agri-food; Acque ed ecosistemi marini; Modelli, metodi e tecniche per il Digital Twin. A questi si affiancano quattro attività trasversali, dedicate allo sviluppo di start-up e spin-off, alla creazione dei Lab Village – laboratori congiunti tra università e imprese –, e alla promozione di iniziative aperte alla cittadinanza.

Il CNR partecipa a iNEST come associato allo spoke 5: "Smart and sustainable environments (manufacturing, working, living)", a leadership UNIPD (Dipartimento di Ingegneria dell'Informazione e Dipartimento di Psicologia Generale), con un budget di poco inferiore a 900 k€. Partecipano alle attività 5 Istituti CNR con sedi in area padovana: IEIIT e ITC del Dipartimento di Ingegneria, ICT e tecnologie per l'energia e i trasporti; ISAC e IRPI del Dipartimento Scienze del sistema terra e tecnologie per l'ambiente; IFN del DSFTM.

Le attività nelle quali il CNR è stato coinvolto sono fortemente integrate nello Spoke di riferimento e vedono una forte sinergia con UNIPD. Il budget CNR ha permesso di finanziare due progetti "giovani ricercatori": IFN e ISAC, tra le attività trasversali previste dal progetto.

Le attività svolte da IFN, come Istituto partecipante del DSFTM, hanno riguardato principalmente l'utilizzo di tecniche di spettroscopia laser applicata alla rivelazione di gas in miscele per applicazioni al settore energia.

Come prosieguo delle attività iNEST, a seguito del Bando emesso dalla Regione Veneto per il rafforzamento delle competenze sviluppate nell'ambito degli Ecosistemi per l'Innovazione Regionale a novembre 2025, il CNR ha ottenuto il progetto TASMA – "Tecnologie Avanzate per lo Smart Manufacturing", a leadership IFN, per il finanziamento di due contratti di ricerca biennali, a guida IFN e IEIIT.

AULA CONVEGNI	18:30

Microelectronic Technologies for the Green Economy

S. A. LOMBARDO
CNR-IMM, Catania, Italy

The project MICROTECH_for_GREEN, financed by the European Union – NextGenerationEU thanks to the Italian Ministry of the Enterprises and of the Made in Italy (MIMIT), part of the initiative IPCEI on Microelectonics and Connectivity, running from June 2024 to May 2029, aims at developing new microelectronics-based technologies in four key areas:

1. Power and Sensor devices
2. Application to Renewables and Agrivoltaics
3. Neuromorphic computing
4. Technologies for Quantum Sensors

The first two areas are focused on a number of enabling microelectronic technologies for new components (discrete power transistors, power Ics, sensors). The test ground of such new technologies will be advanced bifacial photovoltaics and agrivoltaics with the use of PV module level electronics exploiting novel power transistors. The most promising technologies will be tested under operative conditions in an outdoor test field, to reach a TRL 6-7. The areas of development are the following:

- Materials and technologies for novel SiC, GaN, and IGBT power transistors
- Application of such new power FETs to Power optimizers / microinverters for bifacial photovoltaics
- New low-cost recyclable sensors and sensor networks for precision agriculture and agrivoltaics
- New technologies for water purification

To prepare the next generation of microelectronic devices, more exploratory research is important. For this reason we also pursue other activities, one on neuromorphic computing based on memristive devices, and the other on a quantum sensor for magnetometry realized by using color centers in SiC.

Consiglio Nazionale delle Ricerche
Funded by the European Union NextGenerationEU
IPCEI Microelectronics and Communication Technologies

The project of CNR at the IPCEI ME/CT: Micro_Tech_for_Green

IPCEI Microelectronics and Communication Technologies
MICROTECH FOR GREEN

The work is performed in various sections of Cnr-Imm, in Milan (Agrate), Rome, Lecce, and the two Sections in Catania (the Headquarters and at the Univ. of Catania).
In the talk we will describe activities and some first major results.

The BiGyM linear plasma device: upgrade and modelling activities

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[a] *Consiglio Nazionale delle Ricerche (CNR), Istituto per la Scienza e la Tecnologia dei Plasmi (ISTP), Milan, Italy*

[b] *Università degli Studi della Tuscia, Viterbo, Italy*

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* See reference [1] for the full list

The BiGyM at CNR-ISTP in Milan is a linear plasma device dedicated to plasma-material interaction (PMI) studies. It has been upgraded within the NEFERTARI project funded by Next Generation EU, to extend its operational range toward divertor-relevant plasma conditions using new helicon sources, enhanced sample exposure systems, and advanced diagnostics.

This contribution presents the upgrade status and the modelling framework developed to predict BiGyM plasma behaviour and support future experimental interpretation.

Plasma-neutral simulations [2] were performed using SOLPS–ITER to investigate the effects of absorbed power, neutral pressure, and magnetic configuration on plasma parameters in the operational regimes expected for BiGyM. The results indicate that the device can reach electron densities of 10^{17}–10^{19} m^{-3}, electron temperatures of 4–10 eV, and ion fluxes of 10^{21}–10^{23} m^{-2} s^{-1} for different gases under representative operative conditions.

A full 3D electromagnetic model [3] of the new RF antennas was developed in COMSOL Multiphysics to describe helicon-wave propagation within the device. Several device configurations were assessed, in terms of vessel and magnetic field configuration, to determine the best geometry that maximises the deposited power at the sample-holder location, showing differences of up to two orders of magnitude between the least and most favourable cases.

Plasma–material interaction studies [4] were performed using the Monte Carlo impurity transport code ERO2.0 to investigate sputtering and material migration. Eroded wall fluxes are at least one order of magnitude higher compared to the previous machine setup.

The ultimate goal is to couple the three tools into an integrated workflow capable of comprehensively simulating PMI experiments in BiGyM, from plasma generation to the topographical modifications on sample surface.

A picosecond Laser-Induced Breakdown Spectroscopy (LIBS) system will be installed as a new diagnostic on BiGyM, for which dedicated modelling activities [5] were carried out to support its implementation. A laser ablation model was developed in COMSOL and validated against experiments on fusion-relevant materials, reproducing crater geometries with discrepancies generally below 20%. The model provides a basis for future depth-resolved fuel retention measurements and estimation of the heat-affected zone in LIBS experiments.

The modelling activities presented in this work support the device design, providing guidance for operating scenarios and for planning future experimental campaigns.

[1] A. Uccello et al, Front. Phys. 11, 1108175 (2023)
[2] I. Casiraghi et al, Conferenza Italiana sui Plasmi, P.13 (2026)
[3] J. Scionti et al, submitted to Plasma Physics and Controlled Fusion
[4] F. Cani et al, Conference on Plasma-Surface Interactions in Controlled Fusion Devices (2026)
[5] S. Cipelli et al, Journal of Nuclear Materials 620 156315 (2026)

PRP@CERIC – A digitally integrated platform for infectious disease research

ALBERTO CASSETTA[A], SIMONE DAL ZILIO[B]

[a] *CNR - Istituto di Cristallografia*
[b] *CNR - Istituto Officina dei Materiali*

The *Pathogen Readiness Platform for CERIC-ERIC upgrade (PRP@CERIC)* [1] is an interdisciplinary and digitally integrated network designed to enhance and expand the CERIC-ERIC Research Infrastructure in the field of infectious disease research. Funded under the PNRR initiative for the upgrade of Italian Research Infrastructures, PRP@CERIC connects expertise, methodologies, and state-of-the-art instruments across genetics, morphology, chemistry, and biophysics, accessible to both academic and industrial users [2].

By integrating advanced technologies — including high-resolution spectroscopies, imaging, multi-omics, mechanobiology, cryo-electron microscopy (cryo-EM), and bioelectronics — PRP@CERIC enables a comprehensive investigation of infections at molecular, cellular, and in vivo levels.

Bringing together eight leading research institutions, the platform fosters digital connectivity and collaboration among experts in genomics, advanced spectroscopies, and structural biology. Its overarching goal is to strengthen global health and pandemic preparedness by providing integrated resources, promoting international cooperation, and accelerating innovation against infectious diseases.

Within PRP@CERIC, IOM serves as the leading partner among the CNR institutes involved in the platform and plays a central role in the design, implementation, and operation of the cryo-EM laboratory in Trieste. This facility represents a key technological node of PRP@CERIC, also accessible to the broader biophysical community within DSFTM. Furthermore, by enabling high-resolution structural studies of biological macromolecules and pathogen-related complexes, this initiative strategically connects to the ELETTRA 2.0 project, in which DSFTM also plays a prominent role.

EYE LAB – Naples Cryo EM Laboratory: Open Access Infrastructure and Scientific Highlights

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In this contribution, we present EYE LAB – Naples Cryo Electron Microscopy (cryo EM) Laboratory, inaugurated in June 2023 and established through a MUR–PON project co funded by the European Community. The project was conceived to strengthen the European Research Infrastructure for Imaging Technologies in Biological and Biomedical Sciences (EuBI) by expanding advanced cryogenic imaging capabilities and access to high end electron microscopy.

EYE LAB operates as an open research infrastructure following a multidisciplinary and open access model, supporting research activities in structural biology, biophysics, nanomedicine and materials science. The laboratory is equipped with state of the art Cryo Transmission Electron Microscopy (Cryo TEM) and Cryo Scanning Electron Microscopy (Cryo SEM) platforms, including Cryo Focused Ion Beam (Cryo FIB/SEM) instrumentation, enabling high resolution imaging and sample processing under cryogenic conditions.

The facility supports end to end cryo EM workflows, from biological sample vitrification via plunge freezing to data acquisition and advanced image processing. Complete pipelines are available for Single Particle Analysis (SPA) and Cryo Electron Tomography (Cryo ET), including site specific Cryo FIB lamella preparation for in situ three dimensional investigation of cellular and subcellular structures. Integrated data processing and 3D reconstruction workflows allow multiscale analysis, bridging molecular level resolution with cellular architecture while preserving native ultrastructure.

In addition to collaborative research projects, EYE LAB also provides fee for service access to cryo EM instrumentation and expertise for academic users and industrial partners requiring high quality structural data without formal research collaboration. The laboratory is actively involved in competitive national and European research projects, including initiatives within the PNRR framework, further consolidating its role as an operational and attractive cryo EM infrastructure.

Selected highlights of significant scientific results obtained since the laboratory’s inauguration will be presented, demonstrating the impact of advanced cryo EM methodologies across different biological systems. Overall, EYE LAB represents a young but fully operational, sustainable and scalable open research infrastructure, contributing to the long term strengthening of the national and European imaging ecosystem.

The scientific activities of the EYE LAB are exemplified by three key highlights that showcase the laboratory's advanced technological capabilities:

- Structural Determination of HcGALb: We achieved the first-ever atomic model of the HcGALb protein **(Figure 1)**, a bacterial enzyme exhibiting both transgalactosidase and -galactosidase activities. The model reveals an hexameric assembly, solved for the first time within our facility[1].
- Photosystem I in *Posidonia oceanica*: We elucidated the atomic structure of the Photosystem I complex from *Posidonia oceanica* **(Figure 2)**. This ~1 MDa multiprotein assembly was investigated to better understand the molecular mechanisms allowing marine plants to adapt to extreme low-light conditions[2].
- The inhibitory potential of three scorpion venom peptides: the growing threat posed by carbapenemase-producing *Klebsiella pneumoniae* has prompted the exploration of alternative antimicrobial strategies (**Figure 3**). In line with previous efforts to identify novel agents, this study investigates the antibacterial activity of three scorpion venom–derived antimicrobial peptides, termed pantinins. Their efficacy was evaluated against *K. pneumoniae* and multiple KPC-producing clinical isolates[3].

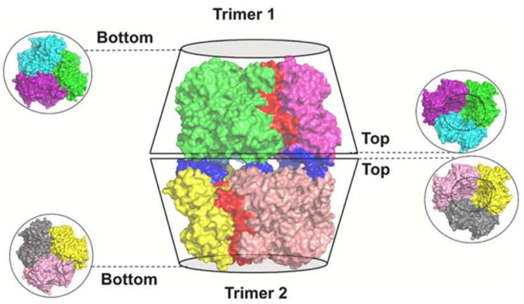

Figure 1: HcGalb atomic model.

Figure 2: PSI photosystem atomic model.

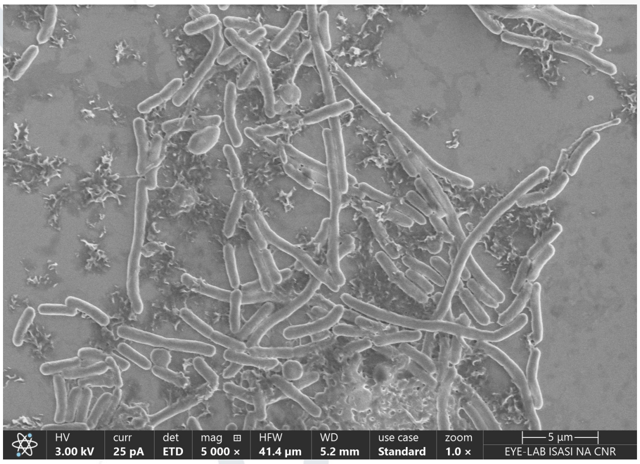

Figure 3: Klebsiella pneumoniae SEM image.

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Plasmonic SERS Nanobiosensors for Ultrasensitive and Automated Detection of Shiga Toxin Variants: From Rigid and Flexible Gold Nanostructures to Intelligent Point-of-Care Diagnostics

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Surface-Enhanced Raman Spectroscopy (SERS) has emerged as a powerful label-free technique for ultrasensitive biosensing in clinical diagnostics. In this work, funded by European Union NextGenerationEU Call PRIN2022, proposal **SENSOSTEC**, we present an integrated overview of three complementary plasmonic SERS platforms for the rapid detection and differentiation of Shiga toxin (Stx) variants associated with Shiga toxin-producing *Escherichia coli* (STEC), a major cause of hemolytic uremic syndrome (HUS). The proposed approaches include rigid silicon-wafer sensors coated with self-assembled gold nanoparticles, flexible Kapton-based substrates functionalized with gold nanoparticles, and nanoengineered plasmonic metasurfaces fabricated by electron beam lithography.

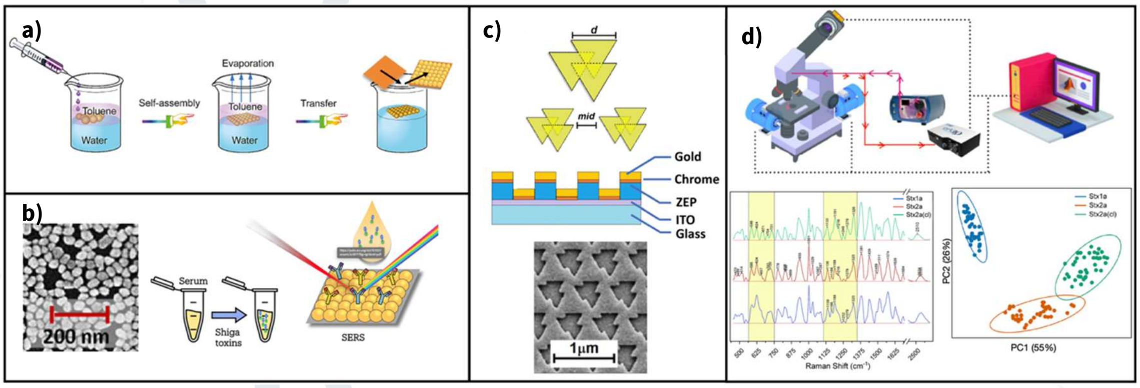

Figure 1. a) Self-assembled gold nanoparticle (Au NP) monolayers fabricated on flexible and rigid SERS substrates. (b) SEM image of the Au NP layer deposited on the Kapton flexible substrate after Shiga toxin functionalization and deposition. (c) Nanoengineered plasmonic metasurface based on nanocavity multilayers together with the corresponding SEM characterization image. (d) Custom-built automated Raman acquisition system developed in the laboratory, including representative SERS spectra and PCA-based discrimination of the different Shiga toxin variants studied.

The plasmonic metasurface platform achieved limits of detection (LOD) of 6.8 pM for Stx1a and 2 pM for Stx2a, while Principal Component Analysis (PCA) enabled accurate discrimination between Stx1a, Stx2a, and cleaved Stx2a through their Raman fingerprints. The silicon-wafer SERS biosensor demonstrated ultrasensitive detection directly in human serum, reaching an exceptional LOD of 0.1 pM (0.007 ng/mL), with high specificity and reproducibility in complex biological matrices. In parallel, the flexible Kapton-based SERS tape exhibited an enhancement factor of 7 × 10^6 and an ultralow LOD of 15 pM for Stx2, highlighting its potential for wearable and point-of-care diagnostics due to its mechanical adaptability and compatibility with aqueous environments. [1] [2] [3] Collectively, these studies demonstrate that nanostructured plasmonic biosensors combined with PCA-assisted spectral analysis provide rapid, cost-effective, and highly selective detection of clinically relevant bacterial toxins without the need for fluorescent labels or complex sample preparation. Furthermore, recent advances in automation and intelligent signal processing pave the way toward fully automated SERS diagnostic systems for real-time clinical monitoring and next-generation point-of-care applications. [4]

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Biophotonics and Nanotechnology for Single-Molecule Biosensing, Multimodal Imaging and Precision Diagnostics

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Biophotonics and nanotechnology are driving the development of highly sensitive, miniaturized platforms for life sciences, molecular diagnostics and precision medicine. The integration of optical sensing, scanning-probe imaging, graphene-based optoelectronics, laser microfabrication and microfluidics enables biomarker detection, bioanalytical sensing, lab-on-chip technologies and advanced biomedical imaging. Single-molecule sensing platforms for clinically relevant biomarkers are developed through multidimensional imaging on biofunctionalized interfaces and graphene-based optoelectronic devices. Scanning-probe approaches, including Kelvin probe force microscopy, enable the quantitative analysis of biomolecular interactions with molecular-scale sensitivity, with demonstrated detection of immunoglobulins, viral proteins, genomic probes and oncologically relevant targets down to the zeptomolar range. Graphene-based optoelectronic biosensors further extend this strategy towards compact devices with ultra-low detection limits [1]. Ultrafast-laser microfabrication provides a further enabling technology for microfluidic and lab-on-chip devices. Femtosecond laser processing allows the fabrication of microchannels, reaction chambers and three-dimensional architectures in biocompatible materials with high spatial resolution and limited thermal damage. Coupling laser-fabricated microfluidics with bio-functional surfaces and optical or electrical readout strategies opens opportunities for biomolecular recognition, controlled cell–molecule interaction studies and point-of-care diagnostics [2].

Advanced optical and photonic sensing platforms broaden the range of detectable targets and device functionalities. Laser-spectroscopy methods, including photoacoustic and photothermal approaches such as QEPAS and LITES, enable selective detection of gaseous molecular species and volatile organic compounds relevant to health, safety and biomedical monitoring. [3,4] Optically reconfigurable photonic devices based on semiconductor lasers and phase-change materials enable programmable miniaturized circuits for imaging, spectroscopy and high-sensitivity detection from the visible to the infrared.

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Bridging Quantum Mechanics and Coarse-Grained Models for Rational Polymer Design

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In polymer rational design, classical simulation methods are often constrained by limited accuracy and transferability at both full atomistic (FA) and coarse-grained (CG) levels. We present a modular, first-principles-based computational protocol for generating consistent atomistic and CG force fields tailored to target polymers, requiring only the chemical formula of the repeating unit as input.

The workflow integrates quantum mechanical calculations, quantum-derived force fields (QMD-FFs), molecular dynamics, and coarse-grained models derived from atomistic simulations into a unified, reproducible multiscale framework.

Within Spoke 7 of PNRR CN-HPC Innovation Grants (IFAB–Lavazza SPM[3] and IFAB–Granarolo PISA), this multiscale computational workflow was developed and validated to describe packaging polymers across the entire modeling hierarchy, from the quantum level to finite element simulations. Its performance is demonstrated for poly(ethylene terephthalate) (PET), poly(ethylene furanoate) (PEF), and poly(L-lactic acid) (PLLA), where both atomistic and coarse-grained models significantly outperform standard force fields in predicting key properties, including density, glass transition temperature, and structural features across scales. The protocol shows high accuracy against experimental data, clearly surpassing conventional modeling approaches.

The results highlight a general, tunable, and systematically refinable approach, providing a robust foundation for in silico polymer design. With further automation, the protocol is well suited for integration into data-driven, high-throughput discovery pipelines.

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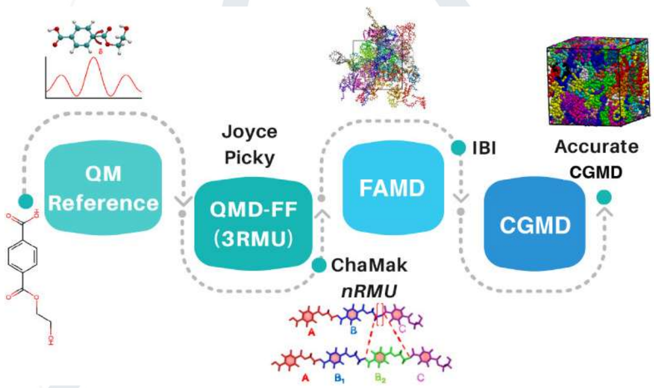

Fig. 1: A schematic representation of the multi-scale workflow for polymers design.

Numerical simulations of copolymer microgels

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Thermoresponsive microgels are colloidal particles, composed by polymer networks, that undergo a sudden change of volume at the so-called volume phase transition temperature (VPTT), which corresponds to the lower critical solution temperature (LCST) of the constituent polymer. This behavior is of interest in several fields and the possibility of tuning the VPTT is crucial for specific applications. The VPTT can be adjusted by changing the polymer chemical nature or introducing copolymers. In this talk, I will discuss how numerical simulations at different length scales can provide valuable insights into the internal topology of copolymer microgels and their phase behavior. I will present a combined approach using monomer-resolved microgels simulations, based on an in-silico synthesis protocol which realistically describes the particle structure [1], along with atomistic polymer chain simulations. By directly comparing numerical form factors with experimental data obtained from small-angle neutron scattering (SANS) experiments, I will show evidence of preferential domain structure in Poly(N-isopropylacrylamide-co-N-isopropylmethacrylamide), P(NIPAM-co-NIPMAM), copolymer microgels [2].

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How biophysics contributes to rare disease research, the case of cblC disease

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Protein folding, the process through which a polypeptide chain explores conformational space to reach its native, functional three-dimensional structure, has long fascinated researchers across several areas of physics, ranging from statistical mechanics and thermodynamics to applied physics. By combining complementary physical approaches such as spectroscopy, microscopy, thermodynamic measurements, and computational modelling, biophysics researchers can unravel the physico-chemical properties of native proteins, thereby elucidating protein structure–function relationships and ultimately providing insight into how these properties are altered by disease-associated mutations.

Using this approach, we recently investigated the properties of MMACHC, a protein involved in vitamin B12 metabolism whose mutations cause a rare inherited disorder known as methylmalonic aciduria and homocystinuria, cblC type. Our research focuses on characterizing the molecular mechanisms underlying MMACHC dysfunction caused by common pathogenic mutations identified in cblC patients. By employing a broad range of biophysical techniques, including spectroscopy, microcalorimetry, molecular dynamics simulations, and light and small-angle X-ray scattering, while also exploiting advanced research infrastructures, we investigated how these mutations affect the thermal stability, structural organization, binding properties, and functional dimerization propensity of MMACHC [1-3].

Understanding the chemical and physical properties of disease-associated MMACHC variants represents an important first step toward the development of precision medicine approaches. In this direction, our biophysical findings contribute to ongoing efforts aimed at identifying therapeutic strategies, such as pharmacological correctors designed to restore protein stability and proper folding.

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Brain network dynamics in health and disease

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Groups of neurons within local and wider networks generate patterns of activity which underlie subjects' behaviour, ranging from sensory to cognitive functions. These patterns of activity are supported by distinct responses of single cells and by the correlated activity of specific group of neurons. Thus, executive functions and a stable sensory representation of the external world is provided by the emergence of ensembles, defined as neurons with correlated activity that participate in the encoding of neuronal information and in the generation of specific behaviours. Distinct patterns of activity are highly dynamic and are modulated by various factors, including the status of the individual, the circadian rhythm and the sleep-wake cycle. Since these mechanisms are essential for brain physiology it is not surprising that these brain rhythms are disrupted in brain pathologies.

My lab is interested in studying how distinct patterns of neuronal activity encode information in physiological conditions and how they get altered in brain pathology. We exploit high density silicon probes (Neuropixel 2. 0) and 2 photon imaging, in vivo, to records the activity of hundreds of neurons in distinct brain areas, including the visual cortex, the olfactory bulb and the prefrontal cortex. To seek to decipher the mechanisms that regulate these patterns of coordinated activity, we investigate not only neuronal activation but also the inhibitory activity that sculpts synchronisation among neurons. Inhibition, has a critical role in shaping single cells responses and correlated activity, but it has been scarcely investigated at systems level, due to the lack of proper tools for imaging inhibitory currents. To this end, we developed a new genetically encoded sensor for Chloride which allows to measure post-synaptic inhibition supported by chloride currents in hundreds of neurons *in vivo*, with single cell and subcellular resolution, by means of 2 photon imaging. This approach enabled us to identify an unexpected dynamic modulation of intracellular Chloride level across the circadian cycle, resulting in different inhibitory drive at night and day. We are therefore investigating how these Cl^- fluctuations affect neuronal activity and computation during the diurnal cycle. We exploit several computational approaches to distil meaningful neuronal information from these large data set, obtained by electrophysiological and optical recordings.

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RNA Catalysis and Ribosome Heterogeneity as Sources of Novel Therapeutic Targets and Biomarkers

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Complex protein–RNA macromolecular machines drive essential cellular processes, from protein synthesis to the processing of coding and non-coding RNAs. Within the CN3—RNA National Centre for Gene Therapy and RNA-Based Drugs, we used (i) advanced classical and QM/MM molecular dynamics simulations and (ii) cutting-edge positional sequencing approaches to elucidate catalytic mechanisms underlying RNA metabolism and identify new classes of biomarkers and therapeutic targets.

In the first project, we investigated protein-assisted ribozymes, including the spliceosome and RNase MRP, as well as RNA-only catalytic machineries. We characterised the catalytic mechanisms of the m^3C methyltransferase METTL6 [1], RNase MRP, and the artificial ribozyme MTR1 [2], which installs chemical modifications on target RNAs [3]. We also developed ensemble-based protocols for refining large cryo-EM RNA structures, with ongoing extensions toward accurate ion localisation. Beyond catalysis, our work uncovered key molecular determinants governing RNA–membrane interactions and RNA-mediated allosteric regulation within the spliceosome.

The second project focused on ribosomes, highly complex and heterogeneous macromolecular machines coordinating protein synthesis. Ribosome dysfunction contributes to diseases including cancer, autism, and neurodegeneration. Once considered uniform, ribosomes are now recognised as heterogeneous entities differing in rRNA variants, epitranscriptional modifications, ribosome-associated proteins (RAPs), and ribosomal protein composition. We leveraged this diversity to identify novel therapeutic targets and biomarker signatures. As a case study, we investigated spinal muscular atrophy (SMA). We demonstrated that SMA involves a previously unrecognised translation-centered vulnerability [4] associated with SMN-bound ribosomes, detectable prenatally in mouse models [5]. Using SMA in vitro and in vivo models, patient fibroblasts, and advanced technologies including ribosome profiling [6] and RiboMeth-seq, we identified disease-associated alterations in rRNA modifications and RAPs. From these datasets, we identified four key RAPs and four 2'O-methylation sites as promising candidates for RNA-based therapeutics [6] and biomarkers. Overall, this work defines a new class of translation-centered biomarkers and establishes the basis for RNA-based therapies that complement existing therapies, offering new strategies for prognosis and treatment in the post-therapy era.

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Synthesis and characterization of two-dimensional diboron trioxide crystal composed by boroxol groups

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Diboron trioxide (B_2O_3) represents a peculiar case among polymorphic oxides, for its vitrified state presents superstructural units – planar ring-shaped boroxol groups, B_3O_6 – that are totally absent in its crystalline polymorphs.

In fact, the crystallization of B_2O_3 can occur only under applied pressure, where the boroxol groups can be disrupted and the triangular BO_3 building blocks can be arranged in a crystalline unit cell. To date, 2D and 3D crystalline polymorphs that incorporate boroxol groups are only predicted theoretically, although their formation in ambient pressure is crucial to rationalize the B_2O_3 ability to vitrify.

Here we present the synthesis of a two-dimensional (2D) B_2O_3 polymorph constituted by boroxol groups bridged by oxygen atoms and arranged in an atomically thin honeycomb lattice (Fig. 1). By means of surface science experimental techniques, as well as *ab initio* calculations [1], we characterized the regular nanoporosity over the mesoscale, the peculiar softness upon isotropic strain, the very weak electronic interaction with the substrate used for growth, Pt(111), and the large band gap in the electronic structure.

This discovery adds one member to the family of 2D materials, proves the existence of boroxol-based B_2O_3 crystalline polymorphs and enables the atomic-scale tracking of individual structural units that can be exploited for in-depth studies on the crystalline-vitreous transition of trioxides.

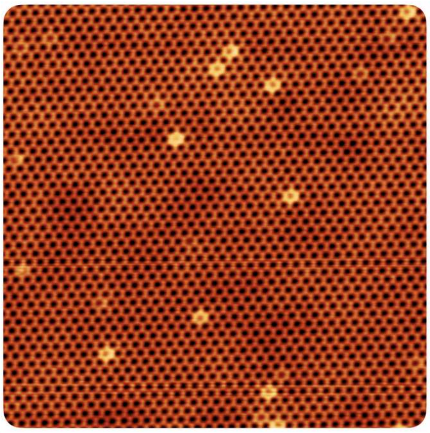

Figure 1: Scanning Tunneling Microscopy topographic image of crystalline 2D B_2O_3 on Pt(111). Image size 30x30 nm^2, bias +1.0 V, tunnelling current 100 pA.

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Sustainable-by-design magnetic materials: from permanent magnets to soft electronics

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The increasing demand for advanced technologies is dramatically raising the consumption of critical raw materials (CRMs), such as rare-earth elements (REEs) and platinum-group metals (PGMs), which are particularly important for high-tech products and emerging green innovations, generating growing concerns regarding resource availability, geopolitical dependence, environmental impact, and long-term sustainability [1]. In this context, the development of high-performance magnetic materials and electronic systems with reduced or no CRM content, together with sustainable fabrication, recycling, and circular-material strategies, is becoming essential for next-generation green technologies.

This contribution presents recent advances in sustainable magnetic materials and electronics based on abundant and recyclable elements for applications ranging from permanent magnets to flexible spintronic systems. A novel and effective chemical synthesis route for magnetically hard $L1_0$-FeNi alloys based on abundant and easily recyclable Fe and Ni elements is discussed [2,3]. These materials show strong potential as sustainable alternatives to high-performance RE-based permanent magnets, combining promising magnetic properties with elemental abundance. In parallel, flexible spin-based thin-film heterostructures free of PGMs are presented as promising building blocks for responsible soft electronic systems targeting wearable technologies, robotics, and biomedical applications. In contrast to conventional spintronic architectures relying on PGMs, the proposed systems exploit non-critical materials such as Ni and Cu while retaining relevant magnetic and transport functionalities, even under bending angles up to 180°, demonstrating their applicability to curved and deformable surfaces while reducing the content of CRMs [4-6]. Preliminary results further show that these architectures can be transformed into rolled microtube powders that retain their magnetic and transport properties despite curvature, opening new opportunities for printable inks and low-energy fabrication of flexible spintronic components.

Acknowledgements: The authors acknowledge funding from the Rome Technopole project through the Spoke 2 activities within the Flagship Projects FP3 and FP6.

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Hybrid electrodes for sustainable energy storage

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The transition towards sustainable energy technologies calls for energy storage devices based on abundant, low-impact and high-performance materials. Lithium-ion batteries currently provide high efficiency and long cycle life, but their fast market expansion is increasingly constrained by the use of critical elements such as cobalt and nickel, whose supply, extraction and geopolitical implications remain a major concern [1].

Organic redox-active materials are attractive candidates for more sustainable batteries because their electrochemical properties can be tailored through molecular design, and they may be obtained from renewable feedstocks or produced through greener synthetic routes [2]. Their practical use, however, is still limited by modest electronic conductivity and by insufficient stability under realistic operating conditions.

Here we explore hybrid organic-inorganic cathode architectures in which organic redox molecules are integrated with nanostructured semiconductors. The inorganic scaffold is designed to facilitate charge transport, enhance the contact between the redox-active component and the electrolyte, and improve the structural and electrochemical stability of the electrode. Particular attention is devoted to the energetic alignment between the valence and conduction bands of the semiconductor and the HOMO-LUMO levels of the organic molecules, with the aim of optimizing charge transfer and storage performance.

Initial results obtained within the ERC Consolidator project '*Hynanostore*' will be discussed to illustrate the working principles and potential of this approach. By combining concepts from materials physics, nanoscience and electrochemistry, this interdisciplinary approach may contribute to next-generation batteries with good performances and reduced environmental impact.

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From Narrow- to Wide-Bandgap Perovskites for Emerging Photovoltaic Technologies

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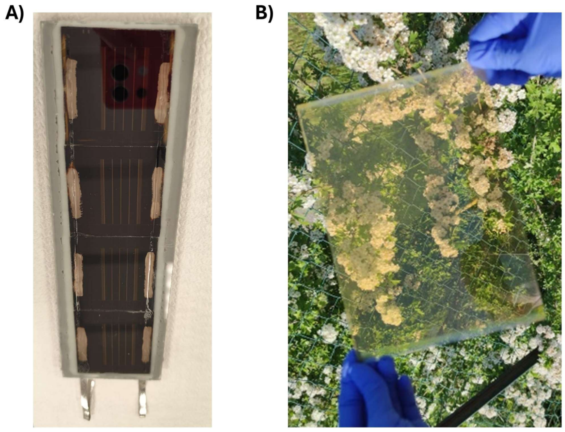
Metal–halide perovskites enable a unique combination of solution-processable manufacturing, semi-Transparency, and compositionally tunable bandgaps, which can be exploited to extend photovoltaic (PV) use cases far beyond conventional rooftop deployment. This contribution presents a unified research activity spanning: (i) scaling up narrow-bandgap perovskite devices toward high-efficiency, large-area generators suitable for power-demanding applications (Figure 1A); (ii) wide-bandgap, semi-transparent perovskite solar cells designed for efficient and visually compatible building-integrated photovoltaics (BIPV) (Figure 1B); and (iii) a pioneering study of perovskite PV operation in underwater environments, enabled by dedicated encapsulation and underwater metrology. Overall, the talk will showcase a series of activities aimed at upscaling, industrialization-oriented processing, and application-driven design of perovskite photovoltaics across markedly



different operational scenarios.

Figure 1 (A) Parallel-connected perovskite mini-modules (5 × 5 cm) assembled into a panel for high-energy-demand applications. (B) Semi-transparent wide-bandgap perovskite device (10 × 15 cm) exhibiting the characteristic amber/yellow tint and high visible transparency, highlighting its suitability for aesthetically compatible BIPV applications.

Molecular dynamics simulation of hybrid metal halide perovskites crystal growth

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Hybrid metal halide perovskites are among the most promising materials for next-generation optoelectronic and photovoltaic applications, owing to their excellent light-harvesting properties and chemical versatility.

However, controlling their crystallization at the atomic scale remains a key challenge, especially for the development of large-area, high-quality films with reduced defect density and improved stability. In this context, molecular dynamics simulations represent a powerful tool to access the microscopic mechanisms of nucleation, precursor aggregation and crystal growth, which are often difficult to resolve experimentally.

A crucial step in this direction is the development of reliable interatomic potentials able to describe both disordered precursor phases and crystalline perovskite structures over long simulation times.

Recently, the MYP2 force field was introduced as an extension of the established MYP0 model for methylammonium lead iodide ($MAPbI_3$), incorporating many-body interaction terms and enabling an improved description of clusters, disordered phases and spontaneous crystallization processes [1].

Building on this framework, we investigated the thermally activated crystal growth of $MAPbI_3$ (Figure 1) from methylammonium iodide and lead iodide precursors under *vacuum* conditions [2], as well as the microscopic mechanisms controlling the synthesis of vertical 2D/3D lead-halide perovskite heterostructures in wet environments [3], by means of large-scale molecular dynamics simulations. Overall, this work highlights the capability of atomistic simulations to provide microscopic insight into perovskite growth processes across different synthesis conditions.

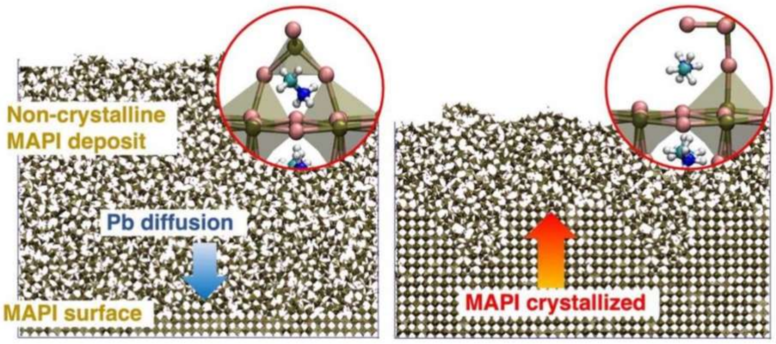

Figure 1: Molecular dynamics simulation of thermally activated crystal growth of $MAPbI_3$.

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[2] S. Argiolas, ACS Nano 2025, 19(13), 12827–12838.

[3] S. Matta, ACS Materials Lett. 2025, 7, 12, 3908–3915

Resource-efficient molecular engineering for energy and optoelectronic devices

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The development of next-generation energy and optoelectronic technologies requires materials that are not only high-performing, but also sustainable across their entire lifecycle. This contribution will present recent activities on the design of molecular materials and processing strategies for energy conversion and optoelectronic devices, with sustainability integrated as a key constraint from synthesis to device operation.

Within this framework, sustainable-by-design synthetic approaches are developed for organic small molecules and phthalocyanine-based materials using low-impact solvents and pot-economical methodologies, aiming to reduce solvent consumption, minimize purification steps, and lower the overall process mass intensity [1-3].

Examples will be presented on environmentally friendly interfacial materials for perovskite solar cells [4] and molecular catalysts for the selective electroconversion of CO2 to methanol [5]. Particular attention is devoted to the interplay between molecular structure, interfacial properties, charge-transport behavior, and operational stability, with the aim of extending device lifetime and reducing material consumption and technological waste. The contribution highlights how low-impact material processing and durable device operation can collectively contribute to more resource-efficient energy conversion and optoelectronic technologies.

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BIBLIOTECA	18:00

Engineering catalysis atom by atom: single-atom platforms on surfaces

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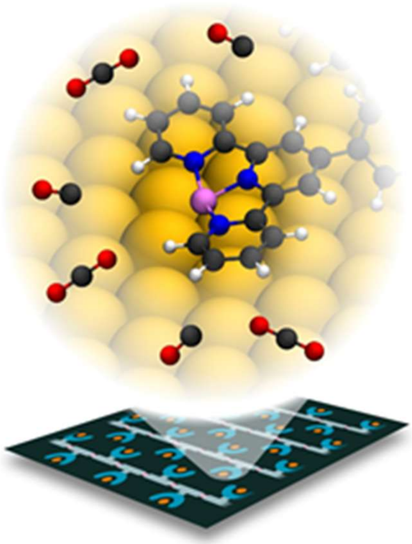
Isolated metal atoms on surfaces represent the ultimate limit of material miniaturization and offer a unique opportunity to explore chemical functionality at the atomic scale. In recent years, single-atom systems have emerged as a powerful platform to investigate fundamental electronic, magnetic, and catalytic phenomena, while also redefining the concept of active sites in heterogeneous catalysis.

A central challenge, however, lies in achieving structural control, tunability, and scalable site density without sacrificing atomic definition. In this talk, a new strategy will be presented, which relies on the realization of single-atom platforms (SAPs): atomically precise, surface-confined architectures in which individual metal atoms are coordinated within engineered organic frameworks [1].

These platforms are fabricated via on-surface synthesis and visualized with state-of-the-art surface science tools, including nc-AFM with functionalized tips at cryogenic temperatures. The combination of molecular precision with surface stability bridges the gap between homogeneous and heterogeneous approaches, while allowing both the design and visualization of well-defined active sites at the atomic level.



The interaction of these SAPs with gaseous molecules will be presented, along with an outlook on future research directions under a recently awarded FIS 3 Consolidator Grant.

[1] A. Kinikar, …, M. Di Giovannantonio. Nat. Commun. 16, 10597 (2025)

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Direct spatiotemporal imaging of charge carrier clouds in operative semiconductor devices

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We introduce Carrier Dynamics by Pockels Imaging (CDPI), a novel all-optical pump–probe technique [1] that enables direct, sensitive, non-invasive imaging of the instantaneous electric field in operating devices. The method builds on a simple but powerful principle: excess carriers dynamically reshape the internal electric field through their own charge, in analogy with heavy marbles deforming a soft, inclined slipway. By exploiting the non-perturbative Pockels effect in transmission configuration, CDPI provides access to the real-space evolution of photogenerated charge clouds, including their trajectory, morphology, width and symmetry, while simultaneously revealing the relationship between internal electric fields and externally measured currents. This ability to correlate internal charge dynamics with electrical signals represents, in our view, a conceptual advance in optoelectronics. Rather than relying on indirect quantities, CDPI establishes a direct experimental observation of microscopic carrier distributions linked to the macroscopic device response. This opens new opportunities for investigating charge transport phenomena and for bridging fundamental physics with device operation. Beyond its conceptual relevance, the technique provides direct access to key transport mechanisms—such as drift, diffusion, carrier–carrier interactions, and trapping/detrapping—without relying on auxiliary assumptions or simplified models. The experimental observations, here reported for bulky CdTe radiation detectors, are supported by comprehensive numerical simulations, further validating the robustness of the approach. To taste the powerful insight achieved by means of our approach, Figure 1 shows the spatiotemporal graph δn(y,t) of an electron cloud moving in an electric field for different photogenerated densities. Importantly, CDPI is intrinsically versatile and can be extended along multiple directions. It is applicable to non-centrosymmetric semiconductors, and more broadly to materials exhibiting a measurable electro-optic response, including perovskites, organic semiconductors, graphene, and established electro-optic platforms such as LiNbO, LiTaO, and BaTiO. The temporal resolution, currently 1 ns, can be further improved using shorter laser pulses, while spatially the technique can be extended to 2D mapping and to microscopic devices.

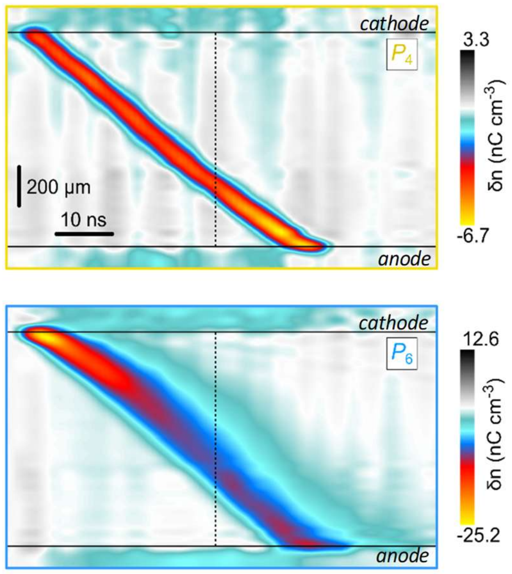

Figure 1. Time-space charts of the electron cloud δn(y,t) under low (top panel) and high (bottom panel) optical photogeneration. In the latter case, a clear modification appears both in terms of cloud broadening and trajectory.

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Engineering emergent phenomena in twisted graphene devices

SERGIO PEZZINI

NEST, Istituto Nanoscienze-CNR and Scuola Normale Superiore, Piazza S. Silvestro 12, 56127 Pisa

Stacks of two-dimensional materials can be leveraged to engineer artificial Hamiltonians based on the layer number and their relative orientation. We have developed techniques to apply this paradigm to CVD-grown graphene crystals, making use of both monolithically grown [1] and artificially assembled multilayers [2].

We will especially focus on structurally asymmetric twisted trilayer graphene, featuring a spontaneous gap opening [1]. This configuration grants access to a flat region in the valence band, where spontaneous isospin polarization of the charge carriers is detected by means of quantum oscillations experiments. Moreover, we will discuss experiments on twisted bilayer graphene at minimal twist angle [2], where collective modes of the moiré lattice are revealed via temperature-dependent electrical transport.

These findings highlight the potential of our approach for the realization and control of emergent quantum phenomena in condensed matter.

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[2] A. Boschi, A. Ramos-Alonso, V. Mišeikis, K. Watanabe, T. Taniguchi, F. Beltram, S. Forti, A. Rossi, C. Coletti, R. M. Fernandes, H. Ochoa and S. Pezzini, arXiv:2511.01691.

Thouless quantum walks in topological flat bands

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Non-Abelian gauge symmetries are cornerstones of modern theoretical physics, underlying fundamental interactions and the geometric structure of quantum mechanics. However, their potential to control quantum coherence, entanglement, and transport in engineered quantum systems remains to a large extent unexplored. In this work, we propose utilizing non-Abelian Thouless pumping to realize one-dimensional discrete-time quantum walks on topological lattices characterized by degenerate flat bands. Through carefully designed pumping cycles, we implement different classes of holonomic coin and shift operators. This framework allows for the construction of quantum walks that encode the topological and geometric properties of the underlying system. Remarkably, the resulting evolution exhibits parity symmetry breaking and gives rise to a dynamical process governed by a Weyl-like equation, highlighting the deep connection between parity and time-reversal symmetry breaking in the system.

BIBLIOTECA	19:00

Bridging length and time scales in materials science with artificial intelligence

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Consiglio Nazionale delle Ricerche, Istituto per la Microelettronica e Microsistemi (CNR-IMM), Z.I. VIII Strada 5, 95121 Catania, Italy

Force fields have proven to be essential tools for studying properties of materials at different length and time scales. Classical force fields describe interatomic interactions using classical equations, enable accurate simulations at a lower computational cost. Recently, driven by higher data availability and powerful high performance computers, a new class of precise and efficient interatomic potentials, such as machine learning interatomic potentials (MLIPs), emerged. This approach marks a paradigm shift, replacing physics-based functional forms of potentials with highly complex mathematical forms based on neural networks. These networks, trained on reference ab-initio datasets, can reproduce high-level quantum mechanical calculations with negligible errors, achieving accuracies comparable to experimental uncertainties. This work showcases the implementation of advanced artificial intelligence methodologies across a range of materials and processes relevant to CNR-IMM research.

Bridging science and technology: decades of Italian optical breakthroughs in international space missions

PAOLA ZUPPELLA[A], PAOLO CHIOETTO[A], LORENZO COCOLA[A], ALAIN J. CORSO[A], VANIA DA DEPPO[A], FABIO FRASSETTO[A], ANTONY HERALD[A], CARMEN NALETTO[A], LUCA POLETTO[A], GABRIELE ZENI[A]

[a] Institute for Photonics and Nanotechnologies, National Research Council, Padova, Italy

For decades, CNR-IFN Padova has spearheaded the design, development, and verification of advanced optical instrumentation for flagship space exploration missions. This long-standing heritage is rooted in a robust institutional network, collaborating closely with national and international partners under the strategic guidance and funding of the European Space Agency and the Italian Space Agency. Key milestones include the scientific leadership of the EnVisS camera for *Comet Interceptor*, the development of the Metis coronagraph for *Solar Orbiter*, and a substantial contribution to the *Ariel* mission, scheduled for launch in 2031. The latter features the largest all-aluminium telescope ever developed for space (see Figure 1), representing a true frontier in cryogenic optical engineering.

The institute's success stems from a unique synergy between high-level scientific research and pure technological application, fostered by long-term strategic partnerships with industrial leaders such as Thales Alenia Space, Leonardo S.p.A., and Media Lario S.r.l.. This collaborative framework enables the team to tackle the most demanding technological challenges, such as maintaining sub-micrometric alignment stability at deep cryogenic temperatures (40-50 K) and qualifying innovative mirror manufacturing and coating processes engineered to survive extreme extraterrestrial environments. The transversality of these competencies is showcased in current high-profile activities: from the development of the EUVST Slit Assembly for *Solar-C* to the MINISPEC spectrometer, designed for high-resolution mineralogical characterization on the lunar surface.

In this evolving landscape, CNR-IFN Padova is a partner of Spoke 1 ("New Generation Systems for Space Observations") within the "Space It Up" project, the Italian Extended Partnership for Space. In this framework, the institute leverages its specialized expertise in developing advanced optical coatings across diverse spectral ranges, providing high-impact solutions engineered to survive the harshest environmental conditions.

Ultimately, this trajectory has consolidated a foundation of long-standing technical expertise and strategic funding opportunities, ensuring Italy's continued impact and leadership in next-generation space observation.

Plasma turbulence in space: latest results and future perspectives

ORESTE PEZZI[A]

[a] *Institute for Plasma Science and Technology, National Research Council of Italy, Bari, Italy*

Space plasmas are excellent laboratories for investigating fundamental physical processes, such as turbulence, magnetic reconnection, and non-linear wave-particle interactions. Turbulence is the key phenomenon bridging the vast scale separation between large, injection scales and small, kinetic scales at which the turbulent energy is converted to plasma particles and, potentially, dissipated.

Understanding kinetic-scale plasma turbulence is hence decisive for tackling the fundamental issues of energy dissipation, heating and particle acceleration, relevant for both space plasmas and far astrophysical systems. As a result of the weak collisionality, turbulence brings the plasma far from the local thermodynamical equilibrium, with particle velocity distribution functions that frequently show a variety of non-equilibrium velocity-space structures. Such an emerging complexity has been recently envisioned as a turbulent cascade occurring in the entire six-dimensional phase space.

I will review some recent results and describe the on-going and future activities on this fascinating topic, funded within the FIS2 Starting Grant “PhAse-sPAce cOmplexity in turbulent nearly-reversible plasmas” (PAPAO)..

AULA 3D	17:00

Epitaxy of semiconductors for quantum technologies

G. BIASIOL

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I will review the activities of the QuantEPI group of IOM Trieste, which are mainly devoted to the synthesis by Molecular Beam Epitaxy of ultra-pure III/As semiconductor heterostructures, with applications in different fields of quantum-related technologies, ranging from quantum computation to nanophotonics and radiation detectors.

We are part of consortia devoted to establishing the foundations of radically new solid-state platforms for fault tolerant, scalable quantum computation. Implementations range from high-fidelity qubit based on the Kitaev Chain to Andreev qubits in hybrid nanodevices. Such technologies are implemented on interfaces between superconductors and semiconductor nanostructures. In particular, high quality metamorphic InAs-based quantum wells coupled to aluminum superconducting thin films formed in situ [1, 2].

A collaboration with Elettra Sincrotrone Trieste is aimed at the realization of X-ray detectors with high photon absorption, fast response times, resistance to radiation damage and RT operation. Detectors based on GaAs avalanche photodiodes are developed for applications in next-generation light sources (high brilliance synchrotron radiation and free electron lasers), high energy physics and medical imaging [4]. An integration with an array of Cross Delay-Lines connected to high-precision Time-To-Digital-Converter is aimed at the realization of a fully-digital 3D imager for gamma and hard-X rays.

[1] A. Benali, P. Rajak, R. Ciancio, J. R. Plaisier, S. Heun, and G. Biasiol, J. Cryst. Growth 593, 1267681 (2022)

[2] M. Sütő, T. Prok, P. Makk, M. Kirti, G. Biasiol, S. Csonka, and E. Tóvári, Phys. Rev. B 106, 235404 (2022)

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Micro&nanoelectromechanical systems based on epitaxial complex oxide thin films for sensors and actuators

LUCA PELLEGRINO

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Complex oxides have the advantages of exhibiting a wide range of physical properties in a class of compatible materials that can be integrated into epitaxial thin film heterostructures. The different selectivity to chemical etchants of prototypical compounds such as $SrTiO_3$ [1], $(La,Sr)MnO_3$ [2], $LaAlO_3$ [3], $EuTiO_3$ [4] and $SrRuO_3$ allows the realization of suspended microstructures made from epitaxial oxides directly deposited on oxide substrates. The etching selectivity opens an “all-oxides” route towards the realization of micro and nanoelectromechanical devices integrating different functionalities into movable heterostructures. These structures can be also employed as templates for the additional deposition of oxides, such as high-Tc superconductors [3], that would not sustain the chemical baths required for the release processes.

I will first review the micromachining processes that we developed with different oxide materials, focusing on the role of epitaxial stress and substrate orientation in determining the three-dimensional geometry of the micromachined structures. We realized different architectures such as cantilevers [4], suspended microbridges [5], trampolines [6] and membranes [7] and characterized their mechanical properties in terms of resonance frequencies and mechanical quality factors, extracting important quantities such as built-in film stress and its Young’s modulus. I will then show how localized heat by a focused laser beam can be employed to trigger a sharp change of lattice parameters of suspended VO_2 thin films microstructures that can be thus employed for the realization of laser-driven micro-actuators [8] working near room temperature for applications in micro/nanorobotics. I will also introduce a micromechanical magnetometer combining a high-Tc superconducting nanostructure and a suspended magnetic resonator [9] and discuss how oxide nanoelectromechanical systems technology could be employed to achieve high sensitivity in magnetic field detection, with envisaged impact in the field of biomagnetism.

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[2] L. Pellegrino et al. Adv. Mater. 21, 2377 (2009).
[3] N. Manca et al. Adv. Funct. Mater. 34(41), 2403155 (2024).
[4] N. Manca et al. APL Mater. 11(10), 101107 (2023).
[5] N. Manca et al. Small 18, 2202768 (2022).
[6] N. Manca et al. ACS Sens. 10(6), 4244 (2025).
[7] N. Manca et al. Adv. Sci. 12, 2412683 (2025).
[8] N. Manca et al. Nano Lett. 20(10), 7251 (2020).
[9] L. Pellegrino et al. Patent No. US11415642B2 and EU Patent No. EP3896470B1

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement and n. 828784 (www.oxinems.eu). This work was also funded by the European Union - NextGenerationEU and by the Ministry of University and Research (MUR), National Recovery and Resilience Plan (NRRP), Mission 4, Component 2, Investment 1.5, project “RAISE - Robotics and AI for Socio-economic Empowerment” (ECS00000035).

AULA 3D	17:30

Ultrafast control and investigation of complex oxides using intense light pulses

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[a] CNR-SPIN, Fisciano (Salerno), Italy, c/o Università di Salerno, Fisciano (Salerno), Italy

Complex oxide materials provide an ideal playground for exploring fundamental physics and designing technological applications. Indeed, the strong interactions between electrons, spins, orbitals, and lattice distortions in such materials give rise to a very rich phase diagram, which can be tuned either by changing the chemical composition or the external parameters. Nowadays, the great technological advances in laser science have enabled the investigation of such materials by means of strong THz light pulses capable not only of resonantly triggering both interband electronic transitions and collective modes, such as phonons, but also of enabling effects that are absent in the weak-field regime.

In this talk, I will present our recent research activities in this context. First, I will provide an example of how intense lasers can enable novel excitation pathways for optical phonons, by discussing a recent experiment on Lanthanum Aluminate [1], where the observed phenomena can be interpreted in terms of a previously unexplored THz-field-induced parametric driving of a Raman-active mode via pairs of acoustic phonon excitations. Then, I will illustrate the interplay of spin-orbit effects and Berry curvature with high-harmonic generation (HHG) in two-dimensional structures of these compounds. I will discuss how the emergence of finite even-order harmonics in such systems necessarily requires broken twofold rotational symmetry in the spin texture, as well as a nontrivial Berry curvature in time-reversal-invariant systems [2].

[1] M. Basini, V. Unikandanunni, F. Gabriele, M. Cross, A. M. Derrico, A. X. Gray, M. C. Hoffmann, F. Forte, M. Cuoco, and S. Bonetti, “Terahertz-driven parametric excitation of Raman-active phonons in LaAlO3,” Physical Review Letters 136, 156902 (2026).*

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AULA 3D	17:45

Criticality as a Resource for quantum devices: Topological Protection, Supersymmetry, and Quantum-Enhanced Sensing

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We show how criticality can be exploited in quantum devices to induce novel phenomena including topological protection against noise, a concrete realization of supersymmetry, and a significant quantum enhancement for parameter estimation.

Criticality enables profound changes in the accessible states of a quantum system, thereby providing a powerful resource for the emergence of unconventional phenomena in quantum technologies. In this talk, I will show how novel quantum devices with spontaneous symmetry breaking can be engineered to exhibit intrinsic topological protection against noise and losses, to concretely realize supersymmetry, and to achieve also significant enhancements in parameter estimation.

A paradigmatic realization is provided by twisted cuprate Josephson junctions, where the d-wave nature of the order parameter induces a transition from a conventional single-well to a symmetric double-well effective potential. In the double-well regime, the quantum tunnelling between symmetry-related configurations enables the encoding of a novel qubit in quasi-degenerate states, called “flowermon”, where decoherence is strongly suppressed due to topological protection [1].

When two twisted junctions are integrated into a SQuiD, the external magnetic flux gives rise to a high degree of tunability yielding a rich phase diagram (Fig.1) which hosts a supersymmetric point in the spectrum. The realization of supersymmetry induces sharp modifications in the device decoherence mechanisms [2].

An external magnetic flux can also be used to induce two-photon generation processes and realize devices known as parametric quantum resonators. These devices can be driven from a low-excitation regime into a highly populated, spontaneously symmetry-broken phase governed by nonlinearities. Near the critical point, small parameter variations induce large changes in the system state, such that arrays of resonators function as highly responsive quantum sensors [3].. This enhanced sensitivity can be quantified by the Quantum Fisher Information, which, in the presence of nearest-neighbour interactions, exhibits Heisenberg scaling with respect to all relevant resources, including the size of the system (Fig. 2).

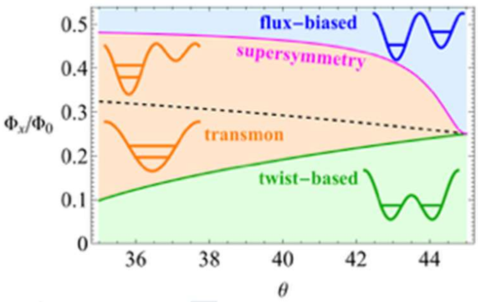

Fig. 1 The phase diagram of two twisted junctions are integrated into a SQuiD (θ is the twisting angle and Φ the magnetic flux) .

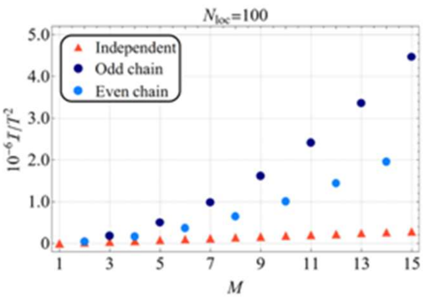

Fig. 2 The quadratic Heisenberg scaling of the Quantum Fisher Information w.r.t of the number M of the resonators of the array.

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AULA 3D	18:00

Bogoliubov Excitations and Topological Effects in Superconducting Qubit Networks

VALENTINA DI MEO[A], ALESSANDRO D'ELIA[B], CLAUDIO GATTI[B], GIORGIO BRIDA[C], EMANUELE ENRICO[C], LUCA FASOLO[C], MIKHAIL FISTUL[D], ELYA EREMIN[D], PATRICK NAVEZ[E], ALEXANDRE ZAGOSKIN[F], PAOLO SILVESTRINI[H], JACOPO SETTINO[I], FRANCESCO ROMEO[J], BERARDO RUGGIERO[H], AND MIKHAIL LISITSKIY[A]

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[b] LNF INFN, Via Enrico Fermi 54, I- 00044, Frascati (Rome), Italy
[c] INRiM, Strada delle Cacce 91, I-10135, Turin, Italy
[d] Ruhr University Bochum, Universitätsstraße 150, D-44801, Germany
[e] University of Montpellier, 163 rue Auguste Broussonnet F-34090 Montpellier, France
[f] Loughborough University, LE11 3TU, Loughborough, United Kingdom
[g] Università degli Studi della Campania "L. Vanvitelli", Viale Lincoln 5, I- 81100 Caserta, Italy
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Superconducting qubit networks (SQN) embedded in high-quality resonators are promising platforms for quantum sensing, because resonator-mediated qubit interactions generate collective microwave-photon states and nonlinear dynamics.

Two-tone spectroscopy measurements performed on SQN with 10 flux qubits at 15 mK reveal a red shift of the qubit excitation resonance frequency with pump power, the appearance of a secondary idler dip near a critical threshold, and a reproducible hysteresis loop under reverse sweeps. A nonlinear Gross-Pitaevskii-like model well reproduces the experimental power-dependent dip position curves and identifies the idler resonance as the second branch of Bogoliubov excitations above a Bose-Einstein like condensate of microwave photons (Fig. 1, left panel, red arrows) [1].

In parallel, exact diagonalization and linear-response calculations on five-qubit arrays show that topology is a genuine design parameter: cross-shaped arrays exhibit longer valid prediction time than linear arrays (Fig. 1, right panel), owing to cooperative interactions between central and peripheral qubits [2]. These results open a concrete route toward improved threshold detectors and stable operation of quantum computing [1,2].

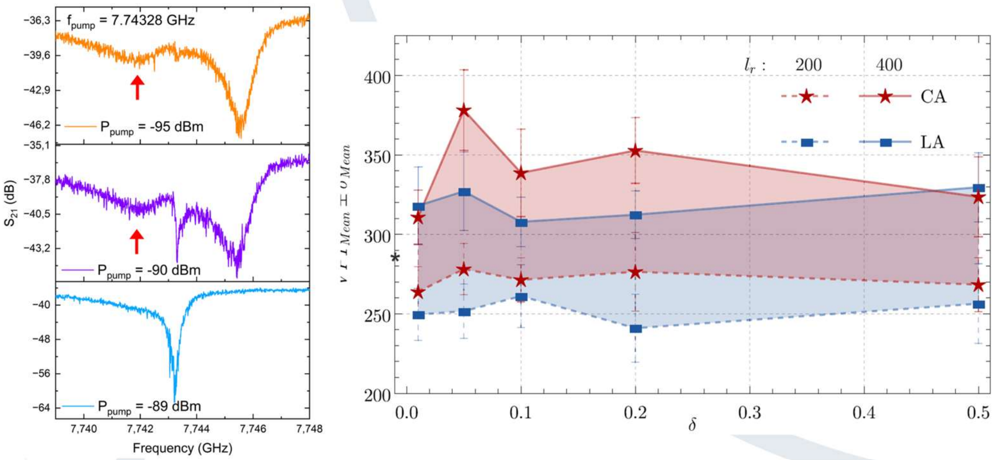

Figure 1. Left panel: dependence of the scattering parameter |S21| of the readout resonator on the probe frequency for three different pump signal powers [1]. Right panel: Valid prediction time as a function of the inhomogeneity parameter δ for the Mackey-Glass prediction task [2].

[1] P. Navez et al, arXiv preprint arXiv:2601.15101 (2026).

[2] J. Settino et al, Quantum Science and Technology 11(2026), 015019/1-015019/19

AULA 3D	18:15

Dynamical universality in a driven quantum fluid of light

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Universal scaling near phase transitions is one of the central ideas of physics, linking the growth of spatial correlations to the slowing down of dynamics. So far, direct experimental access to this critical behavior has remained largely confined to equilibrium many-body systems, and especially to static critical behavior. Here we probe how universality emerges in a driven quantum fluid of light formed by exciton–polaritons in a semiconductor microcavity. By probing the fluctuation-dominated disordered phase below the condensation threshold, we directly measure both the static growth of the correlation length ξ and the dynamical slowing down of the relaxation time τ. We find that these quantities obey the universal relation $\tau \propto \xi^z$ where $z \approx 2$ is the dynamical exponent revealing diffusive dynamics of a non-conserved order parameter. Our results extend the physics of critical dynamics from equilibrium matter to driven optical systems, bridging quantum condensates and lasers.

[1] I. Gnusov, et al., arXiv preprint, arxiv.org/2605.02397 (2026).

Quantum nonlinear optics and spectroscopy

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We present the results about the investigation of the quantum properties of twin beams (TBs) generated through cascaded second-harmonic generation and optical parametric oscillation in a doubly resonant system developed during the NQSTI project. TBs produced via parametric down-conversion are characterized by strong intensity correlations and corresponding phase anti-correlations. These properties result in squeezing of both the intensity difference and the phase-sum observable, ultimately leading to entanglement between the two optical fields. This is why TBs are a favoured candidate for the implementation of continuous-variable quantum communication and computation protocols, as well as to improve precision measurements beyond the shot-noise limit. In our specific configuration, the complex interactions between cascaded second order processes lead to a variety of nonclassical effects that are not accessible via each single nonlinear process. Whereas nonclassical intensity correlations have already been experimentally observed [1], the present work focuses on the implementation of a setup capable of demonstrating TBs entanglement. Bipartite continuous-variable entanglement can be verified using the inseparability criterion introduced by Duan, which is based on the total variance of Einstein-Podolsky-Rosen type operators. Applying this criterion requires the simultaneous measurement of specific quadrature combinations, namely the difference of the amplitude quadratures and the sum of the phase quadratures of the TBs.

Although squeezed light has been used in atom interferometry and gravitational-wave detectors, its application to molecular spectroscopy, especially for the detection of cold particles, remains underexplored. As part of Spoke 3 of the NQSTI project, we have realized an original apparatus for metrology-grade cavity ring-down spectroscopy of buffer-gas-cooled molecular samples [2]. It combines the ultra-low vibration of a remote-motor, two-stage pulse-tube cryocooler with an advanced optical setup that achieves active stabilization of the high-finesse resonator via a robust frequency-lock chain. This will open the door to accurate measurements of basic spectroscopic parameters (most importantly transition center frequencies) for a broad class of molecular species in the range of a few Kelvins, which is particularly relevant for new tests of fundamental physics at the electron-volt energy scale (e.g. time stability of the proton-to-electron mass ratio, fifth-force searches). Furthermore, starting from state-of-the-art cavity-enhanced techniques, novel approaches will be explored seeking to combine cold-molecule spectroscopy with squeezed-light sources to attain measurement precision beyond classical limits.

[1] S. Castrignano *et al*, Opt. Lett. 49 (2024), 1733-1736.

[2] P. Maddaloni *et al*., MOLECULAR PHYSICS (2026) e2640162.

AULA 3D	18:45

From quantum simulation to quantum computation with ultracold matter

LUCA TANZI[a] AND THE COLD MATTER & QUANTUM SIMULATION GROUP AT CNR-INO

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At CNR-INO we use ultracold atomic gases as highly controllable platforms for quantum many-body physics. By cooling atoms to nanokelvin temperatures and manipulating them with tailored light fields, we can engineer artificial quantum matter with tunable interactions and geometry, providing a flexible interface between quantum optics, quantum information, and condensed-matter physics.

This approach enables quantum simulation of challenging problems in natural materials, as well as the realization of novel quantum states beyond what is accessible in conventional solid-state systems [1, 2, 3]. We are now extending this level of control to the single-atom regime. By loading neutral atoms into optical tweezers, one can deterministically prepare and manipulate individual atoms, assembling programmable arrays with single-particle control [4]. These systems can act both as quantum simulators and as qubits coupled by controlled interactions.

This capability naturally enables the implementation of digital operations alongside analog approaches. In this talk, I will present an overview of cold-atom activities at CNR-INO and discuss recent developments toward quantum computation with ultracold matter.

[1] L. Tanzi, Nature 574 (2019), 382.
[2] T.-W. Zhou, et al., Science 381 (2023), 427.
[3] G. Del Pace, et al., Science 390 (2025), 1125-1129.
[4] V. Giardini, Atoms, 14(1) (2026), 1.

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